CORE
Metadata, citation and similar papers at core.ac.uk
Provided by Elsevier - Publisher Connector

ELSEVIER
Available online at www.sciencedirect.com
SciVerse ScienceDirect
Energy Procedia 14 (2012) 1421 – 1426
Energy Procedia

ICAEE2011

Carbon mitigation potential of Jatropha Biodiesel in Indian context

K.Sudhakar[a], M.Rajesh[b*], M.Premalatha[c]
[a]*Assistant Professor, Energy Department, Maulana Azad National Institute of Technology, Bhopal - India*
[b]*Energy Department, Maulana Azad National Institute of Technology, Bhopal - India*
[c]*Associate professor, CEESAT, National Institute of Technology, Tiruchirapalli - India.*

Abstract
With depleting supply of fossil fuels and energy prices reaching historical high, biodiesel as an alternative fuel is increasingly drawing attention. Biodiesel is regarded as sustainable energy source and would become as important as petroleum products of the present time. The biodiesel is a substitute or an additive to diesel fuel and because of its low emission make it an ideal fuel for diesel engine. The biodiesel does not require any modifications to be used in a CI engine. The purpose of this study is to investigate the characteristics of jatropha biodiesel and its carbon mitigation potential in Indian context.

© 2011 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of the organizing committee of 2nd International Conference on Advances in Energy Engineering (ICAEE). Open access under CC BY-NC-ND license.

Keywords: Jatropha, Biofuel, Esterification, Emissions, Biodiesel

1. Introduction

Biodiesel refers to a vegetable oil or animal fat based diesel fuel consisting of long-chain alkyl (methyl, propyl or ethyl) esters [1, 2]. Biodiesel is typically made by chemically reacting lipids with an alcohol. Biodiesel can be produced from plant oil, animal fats and waste cooking oils. These feed stocks have been suitable for biodiesel production and its application in diesel engine. However the demand of biodiesel production is increasing every year and oil crops are compromising food crops. So other sources of biodiesel from non food crops have to be identified and commercialized. Biodiesel is meant to be used in standard diesel engines and is thus distinct from the vegetable and waste oils used to fuel converted diesel engines. Biodiesel can be used in pure form (B100) or may be blended with petroleum diesel at any concentration in most injection pump diesel engines [3]. Biodiesel is an alternative diesel fuel which can be derived from both edible and non edible biological sources and environmentally beneficial [4].

* Corresponding author. Tel.: +91-755-2670327; fax: +91-755-2670562.
E-mail address: rajesh0233@gmail.com.

1876-6102 © 2011 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of the organizing committee of 2nd International Conference on Advances in Energy Engineering (ICAEE). Open access under CC BY-NC-ND license.
doi:10.1016/j.egypro.2011.12.887

Much of the world uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix:

- 100% biodiesel is referred to as B100
- 20% biodiesel, 80% petrodiesel is labelled B20
- 10% biodiesel, 90% petrodiesel is labelled B10
- 5% biodiesel, 95% petrodiesel is labelled B5

1.1Biodiesel Feedstock

A variety of oils can be used to produce biodiesel. These include:

- Virgin oil feedstock, palm, rapeseed, sunflower, mustard, corn and soyabean oils are most commonly used. It can also be obtained from non food crops such as Jatropha, karanj, castor and neem [5, 6].
- Waste vegetable oil (WVO) [7].
- Animal fats including tallow, lard, yellow grease, chicken fat, and the by-products of the production of Omega-3 fatty acids from fish oil [8].
- Micro Algae, which can be grown using an open raceway pond or through photo bioreactor [9]. After Algae, the second best source of oil for harnessing biodiesel is Jatropha.

1.2 Jatropha in Indian context

Jatropha curcas is the most widely used variety for the purpose of biodiesel extraction. Jatropha curcas is found in the tropics and subtropics and likes heat, although it does well even in lower temperatures and can withstand a light frost [10]. Its water requirement is extremely low [11] (1 litre per plant per day and can be provided once in 15 days which costs Rs. 20 per hectare for each watering) and it can stand long periods of drought by shedding most of its leaves to reduce transpiration loss. Jatropha curcas is also suitable for preventing soil erosion and shifting of sand dunes.

There a number of varieties of Jatropha. Best among these is Jatropha curcas. Some of the others are

- Jatropha curcas (nontoxic)
- Jatropha integrerrima
- Jatropha gossypifolia
- Jatropha glandulifera
- Jatropha tanjorensis
- Jatropha multifida

Jatropha oil is lauded as being sustainable, and that its production would not compete with food production, as it can also survive and sustain in unfertile land, it can grow even on gravelly and sandy soils. It can thrive on the poorest stony soil. Jatropha can be intercropped with many cash crops such as coffee, sugar, fruits and vegetables, which offers both fertilizer and protection against livestock. Jatropha needs at least 600mm of rain annually to thrive however it can survive three years of drought by dropping its leaves and act as a wonderful soil enriching mulch. Figure 1 shows the jatropha plant and Figure 2 shows the harvested jatropha seeds.

Fig. 1: Jatropha plant

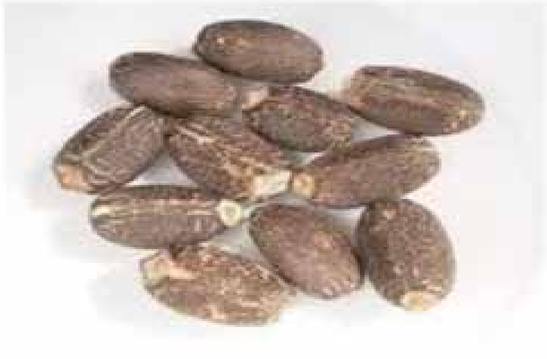

Fig.2: Harvested Jatropha seeds

Oil content of Jatropha seeds varies from 28% to 40%. The oil contains 21% saturated fatty acids and 79% unsaturated fatty acids. There are some chemical elements in the seed, Cursin, which are poisonous and render the oil not appropriate for human consumption. These factors render Jatropha oil as most appropriate form for producing biodiesel substituting petroleum diesel. It has desirable physicochemical and performance characteristics comparable to diesel. Each jatropha seedling should be given a 2m x 2m area to grow. 20% of seedlings planted will not survive. Jatropha seedlings yield seeds in the first year after plantation. After the first five years, the typical annual yield of a jatropha tree is 3.5kg of beans. The oil is extracted from seeds using an oil press (expeller type used) which can extract around 75% of oil from seeds. The residue can be used as biomass feedstock to power electricity plants or used as fertilizer (it contains nitrogen, phosphorus and potassium). India is keen on reducing its dependence on coal and petroleum to meet its increasing energy demand and encouraging Jatropha cultivation is a crucial component of its energy policy.

2. Methodology

2.1 Materials

Jatropha plantation was done in 2008 at Energy centre, MANIT, Bhopal (23° 16' N, 77° 36' E).Five kg of Jatropha seeds were obtained from the plantation. Then the kernel is obtained from the seeds by removing the shell covering them, the oil content of the kernel is around 50-60%. The kernel is processed by a hand operated oil expeller (Rajkumar Agro Engineers Pvt. Ltd. Nagpur, India). The oil obtained is then filtered to get pure oil sample. Jatropha oil of around 1 litre was obtained using hand operated oil expeller. Analytical reagent grade chemicals such as Methanol and Potassium Hydroxide (KOH) were procured from high purity laboratory chemicals (Mumbai, India). The experiments were carried out in a 500 ml flask at Bio-energy laboratory of the Department of Energy. The reaction mixture was agitated using a hot plate magnetic stirrer.

2.2 Biodiesel production process

Transesterification is the process of exchanging the organic group R″ of an ester with the organic group R′ of an alcohol. These reactions are often catalyzed by the addition of an acid or base catalyst. Triglycerides (1) are reacted with an alcohol such as ethanol (2) to give ethyl esters of fatty acids (3) and glycerol (4). The transesterification is represented by the general equation [12].

RCOOR’ + R”OH →RCOOR” + R’OH (1)
Where R, R’, R” indicates Alkyl group.

In industrial processes we generally incorporate base catalysed reaction. The base-catalyzed transesterification of vegetable oils proceeds faster than the acid-catalyzed reaction. Empirically 6.25 g /L NaOH produces a very usable fuel. One uses about 6 g NaOH when the WVO is light in colour and about 7 g NaOH when it is dark in colour. 20% Methanol by weight and 4% of the potassium hydroxide catalyst was mixed with Jatropha oil. Then the mixture was stirred at constant speed of 800 rpm at 55^{o}C for 20 min. there after the mixture was poured into a conical burette and allowed for cooling at room temperature for 6-8 hrs, for settling and separation of glycerine at the bottom. After settling the upper layer containing biodiesel was transferred into another conical flask for washing with equal amount of water. The biodiesel was heated upto 105^{o}C for 10-15 min to remove excess water. And this mixture left undisturbed at room temperature for about 12 hrs. The biodiesel thus obtained is tested for different parameters such as density, viscosity, flash point, fire point and calorific value. The methods adopted to measure various properties are listed in Table 1.

Table 1: Fuel properties and method of measurement

Parameters	Unit	Method	Standard
Gross calorific value	MJ/kg	Bomb calorimeter	D 240-02
Viscosity	mm^2/s	Redwood viscometer	D 445-03
Density	kg/m^3	Relative density bottle	D 4052-96
Flash point	^{o}C	Pensky-Martens closed cup	D 93-02a

3. Results and Discussion

3.1 Biodiesel characterisation

The important fuel properties of crude Jatropha oil and its biodiesel were measured and compared with that of diesel (Table 2). It can be seen from the Table 2 density of Jatropha biodiesel is slightly higher than that of diesel.

Table 2: Fuel properties of Jatropha oil and their biodiesel in comparison with diesel

Properties	Crude jatropha oil	Jatropha biodiesel	Diesel
Viscosity (mm^2/s)	35.4	4.59	4.84
Flash point (^{o}C)	226	182	71
Fire point (^{o}C)	236	190	76
Gross calorific value (MJ kg^{-1})	39.76	45.2	46.22
Density (g ml^{-1})	0.94	0.88	0.83

Flash point and fire point are important temperature specified for safety during transport, storage and handling. The flash point and fire point of Jatropha biodiesel was found to decrease after transesterification when compared to raw oil, which shows that its volatility characteristics had improved and it is also safe to handle. The higher flash point of biodiesel is attributed to longer chain. Kinematic viscosity of Jatropha oil and Jatropha biodiesel is 35.4 mm^2/s and 4.59 mm^2/s respectively at 40^{o}C. The kinematic viscosity of Jatropha oil is higher than diesel. The kinematic viscosity of Jatropha biodiesel is quite comparable with the diesel and hence acceptable as per ASTM standards for biodiesel. This property is important as it influences the combustion efficiency of the fuel [13, 14].

3.2 Land Requirement for Jatropha plantation

Jatropha trees are productive for up to 30-40 years. 2,200 trees can be planted per hectare (approx 1,000 per acre).1 hectare should yield around 7 tonnes of seeds per year and around 2.2-2.7 tonnes of oil. Press cake (seedcake) is left after the oil is pressed from the seeds. This can be composted and used as a high-grade nitrogen rich organic fertilizer. The remaining oil can be used to make skin friendly soap. Based on these data, we can conclude that around 2000 litres of oil can be produced per hectare of land in India. If this were to be used as a source for meeting total India's oil requirements (4.06 million barrels estimated for 2011 by EIA) [15], then 86.94 million hectares of land is required for cultivation. This accounts to approximately 26% of the country's total land area.

Total land area of India = 328 million hectares [16]
Jatropha Crude oil yields= 2.5 tons /ha/year
Jatropha Biodiesel Yield = 17.04 barrels/hectare/ year
Current Crude oil consumption (expected for 2011) = 1481.9 million bbl/yr.
Land Area required to meet the current Requirement = $\frac{1481.9 \text{ million}}{17.04} = 86.96 \text{ million ha}$
.
% Land Area Required to substitute the current consumption of oil through Jatropha biodiesel =

$$\frac{86.96}{328} \times 100 = 26.51\%$$

3.3 Carbon Sequestration potential

Emission Certificates value of 1 carbon credits = 30 USD per ton of CO_2. [17]
CO_2 Sequestration Potential of Jatropha biodiesel = 10 tons/ha/yr CO_2 [18]
Carbon Credits from the trade of emission certificates for CO_2 sequestration = USD 300/ha/yr.

Table 3: Estimates of Potential Benefits of Jatropha Plantations

Portion	Quantity	Value (USD)	Revenues (USD/ha)
Press cake (60%)	4.2 T/ha	0.03/kg	126
Oil (35%)	2000L/ha	0.60/litre	1200
Sediment (5%)	0.35 T/ha	0.15/kg	52.5
Carbon Credit			300
Total			1678.5

Total revenue of 1678.5 USD can be realized per hectare of jatropha plantation.

3.4 Socio-economic benefit

Instead of looking to the Mideast for oil, the country could look into the development of bio-fuels. Producing more bio-fuels will save foreign exchange and reduce energy expenditure. Bio-fuels create new markets for agricultural products and stimulate rural development because bio-fuels are generated from crops; they hold enormous potential for farmers. Today, many of these farmers are too small to compete in the global market, especially with the playing field tilted against them through trade distorting agricultural subsidies. But bio-fuels have enormous potential to change this situation for the better. At the community level, farmers who produce dedicated energy crops can grow their incomes and increase their own supply of affordable and reliable energy. At the national level, producing more bio-fuels will generate new industries, new technologies, new jobs and new markets.

4. Conclusion

Biodiesel, an renewable, cheap and inexhaustible source of energy can be a good substitute for diesel fuel. The Jatropha oil based bio-fuel production is very attractive and has a great potential to be used in large scale as fuel in diesel engine for developing countries like India. Jatropha Plantation in non-traditional agronomic areas would generate the following positive outcomes:

- Produce sustainable and relatively inexpensive fuel.
- Provide Carbon Reduction.
- Provide support to the local economy.
- Provide rural employment.
- Improves energy security of the nation.

Large scale cultivation of jatropha would be the most sustainable option and has got potential socioeconomic and environmental benefits.

References

[1] Ma, F., Hanna, M. A., Biodiesel production: A review, Bio resource Tech. :1-15.

[2] Demirbas, A., Biodiesel Fuels from Vegetable Oils via Catalytic and Non Catalytic Supercritical Alcohol Transesterification and other Methods: A survey. Energy Convers Management. 2003; 44:93-109.

[3] pugazhvadivu M and Rajagopan S. Investigations on a diesel engine fuelled with biodiesel blends and diethyl ether as an additive. Indian J.Sci.Technol. 2009; 2(5): 31-35.

[4] Xue F, Zhang Xu, Luo H, Tan T. A new method for preparing raw material for biodiesel production. Process Biochem. 2006; 41(7):1699-1702.

[5] Hanumantha Rao YV, Ram Sudheer Voleti, Sitarama Raju AV and P. Nageswara Reddy. Experimental investigations on jatropha biodiesel and additive in diesel engine. Indian J.Sci.Technol. 2009;2(4): 25-31.

[6] Math MC, Sudheer prem Kumar and Soma V. Chetty. Optimization of biodiesel production from oils and fats with high free fatty acids. Indian J.Sci.Technol. 2010;3 (3):318-321.

[7] Cankci, M., and J. Van Gerpen. Biodiesel production from oils and fats with high free fatty acids. Transactions of the ASAE. 2001;44: 1429-36.

[8] Wen, Z., R. Grisso, J. Arogo, and D. Vaughan. Biodiesel Fuel, Virginia Cooperative Extension publication. 2006: 442-880.

[9] Chisti, Y. Biodiesel from microalgae. Biotechnology. Advances. 2007; 25: 294-306.

[10] Divakara BN, Upadhayaya HD, Wani SP, Gowda CLL. Biology and genetic improvement of jatropha curcas L.: a review, Appl Energy. 2010; 87(3):732-742.

[11] Francis G, Edinger R, Becker K, A Concept for simultaneous wasteland reclamation, fuel production and socio-economic development in degraded areas in India: need, potential and perspective of jatropha plantations, Nat Resour Forum. 2005;29:12-24.

[12] Conceicao MM, Candeia RA, Silva FC, Bezerra AF, Fernandes VJ Jr, Souza AG. Thermoanalytical characterization of castor oil biodiesel, Renew Sustain Energy Rev. 2007;11(5): 964-975.

[13] Igwe, I. O., The Effects of Temperature on the Viscosity of Vegetable Oils in Solution, Industrial Crops and Products. 2004; 19:185-190.

[14] Ryan III, T. W., Dodge, L. G., Callahan, T.J., The Effects of Vegetable Oil Properties on Injection and Combustion in Two Different Diesel Engines. J. Am. Oil Chem. Soc. 1984; 61(10):1610-1619.

[15] Energy Information Administration (EIA). 2006a. Annual Energy Outlook. Washington, DC: DOE/EIA.

[16] "India Details on Official India Government website". Government of India. http://india.gov.in/knowindia/profile.php. Retrieved June 8, 2011.

[17] Nordhaus, William (2008). "A Question of Balance - Weighing the Options on Global Warming Policies". Yale University Press. http://nordhaus.econ.yale.edu/Balance_2nd_proofs.pdf.

[18] Tamilnadu Agricultural University,Coimbatore.A report on Jatropha Production Technology. http://www.tnenvis.nic.in/images/evjatropha.pdf